

## Towards sustainable polio vaccine distribution: Evaluating a green metrics framework in Indonesia's pharmaceutical industry

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### ABSTRACT

This study endeavors to evaluate the effectiveness of green distribution and green supply chain practices at PT Bio Farma (Persero) in relation to polio vaccine products. The ultimate objective is to establish and attain future green distribution targets. The research methodology utilizes the Green Supply Chain Operations Reference (Green SCOR) model and the Analytical Hierarchy Process (AHP) to analyze the production and distribution data of polio vaccine (OPV) and inactivated polio vaccine (IPV) products from January to December 2023. The performance values for each key component of Green Distribution and Green Supply Chain are as follows: Plan = 22.9, Source = 16.60, Make = 21.53, Deliver = 11.24, and Return = 7.08. The total performance value for Green Distribution and Green Supply Chain is 79.41. According to APICS standards, the performance of Green Distribution and Green Supply Chain is rated as “Good”. Future performance improvements will focus on supply chain and collaborative planning, establishing long-term partnerships with suppliers and customers, optimizing environmentally friendly transportation, and developing the enterprise information system. Our study proposes that the distribution and logistics managers at PT Bio Farma should persistently monitor and assess their operations to enhance the efficiency of their green distribution and green supply chains. By doing so, they can ensure the successful attainment of performance objectives for disseminating the polio vaccine in Indonesia. This research presents a significant advancement by incorporating the Green SCOR framework into the specific domain of polio vaccines, emphasizing sustainability and environmental efficiency. This approach paves the way for new avenues of investigation in green supply chain research and offers a novel viewpoint on how the pharmaceutical industry, specifically vaccine distribution, can utilize sustainable practices to enhance their operations while mitigating environmental ramifications.

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## 1. Introduction

Polio remains an ongoing and severe epidemic that has resulted in the paralysis of millions of children in recent years (Jin et al., 2022). This disease, which primarily affects children, induces paralysis and nerve damage and can even lead to death. According to Zomahoun et al. (2021), approximately 5-10% of reported polio cases end in fatality, with one child being left permanently paralyzed. Since its establishment in 1988, the Global Polio Eradication Initiative (GPEI) has made noteworthy progress in curbing polio cases worldwide. This initiative has successfully reduced polio-endemic countries from 125 to just 3, significantly diminishing the overall number of polio cases by 99% (Fahmy et al., 2017). In the case of Indonesia, a polio transmission risk assessment was conducted by the World Health Organization (WHO) in 2018 at both the national and provincial levels. The findings revealed that 23 provinces in Indonesia, accounting for 76.5% of the total, were classified as being at high risk, while the remaining nine provinces, or 23.5%, were categorized as medium risk.

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Yogyakarta and Bali were the only two provinces deemed to have a low risk of polio transmission (Kementerian Kesehatan Republik Indonesia, 2020). To mitigate the risk of polio transmission, the Indonesian government includes the polio vaccine (OPV) and a dose of inactivated polio vaccine (IPV) as part of its routine immunization program for young children (Holmes et al., 2017). The responsibility for producing and distributing polio vaccines in Indonesia has been entrusted to PT Bio Farma (Persero), a state-owned company. Since the development of the polio vaccine in 1993, PT Bio Farma's production capacity has reached 1.7 billion doses annually, enabling the fulfillment of national requirements and capturing up to 60% of the global market share (Prayogi & Wandebori, 2020).

The distribution performance of PT Bio Farma's (Persero) polio vaccine in Indonesia has only achieved 90% for OPV4 and less than 80% for IPV. Thus, there is a need to enhance the distribution performance to ensure the success of the national polio eradication program (Kementerian Kesehatan Republik Indonesia, 2020). The vaccine industry should consider adopting environmentally friendly, green distribution practices to mitigate carbon emissions, energy consumption, and waste generation. Green distribution encompasses several strategies, including efficient delivery from manufacturers to end consumers, improved cold chain management, and reduced packaging waste (Yadav & Kumar, 2023; Mahmud et al., 2023). Moreover, the concept of a green supply chain can promote sustainable practices in industries and minimize adverse environmental impacts (M. Khan et al., 2023; Sharma et al., 2021; Tseng et al., 2019; Yildiz Çankaya & Sezen, 2019). It is crucial for PT Bio Farma (Persero) not only to meet the national distribution targets but also to produce and distribute polio vaccines under eco-friendly regulations. Additionally, the implementation of green distribution practices can also support optimization of transportation and inventory management (Muduli et al., 2020; M. Khan et al., 2023; Cvirik & Daneshjo, 2022). The notion of the green supply chain pertains to the integration of ecologically responsible managerial practices at each phase, encompassing green procurement and green distribution (Passetti et al., 2018; Srivastava, 2007). Green distribution, which constitutes a facet of the green supply chain, specifically emphasizes the adoption of green transportation and warehousing to enhance the organization's environmental performance (Nie & Zhang, 2023; Yang et al., 2022; Dzikiarsyah et al., 2023).

As of early January 2023, PT Bio Farma (Persero) has implemented green distribution as part of its comprehensive green supply chain program. Thus far, no research has been conducted on the measurement of green supply chain performance and green distribution of polio vaccines in Indonesia, rendering an assessment of the level of success impossible. The absence of measurement and evaluation of distribution performance will impede the effectiveness of the distribution process and exacerbate negative environmental impacts. The analysis of available literature indicates a significant research gap regarding the application of the Green Supply Chain Operating Model (Green SCOR) in polio vaccine distribution. While there are studies examining specific aspects of green supply chains in the pharmaceutical industry, the specific utilization of the Green SCOR model as a framework to enhance the green distribution performance of polio vaccines has not been adequately explored. This gap presents an opportunity to bridge the knowledge deficiency and gain profound insights into the potential application of the Green SCOR model to optimize the vaccine supply chain with a focus on environmental sustainability and efficiency.

Hence, the objective of this study is to comprehensively assess the performance of green distribution and the green supply chain at PT Bio Farma (Persero) in the context of polio vaccine products. This will be achieved through the application of the Green SCOR framework, which will facilitate the establishment of future green distribution objectives. The specific aim of this study is to pinpoint areas for improvement and formulate strategic recommendations aimed at enhancing operational efficacy and mitigating the environmental impact of distribution activities.

The novelty of this research lies in its pioneering exploration of the application of the Green SCOR framework in the relatively unexplored realm of green polio vaccine distribution. By integrating the Green SCOR framework, traditionally employed in diverse industries, into the specialized domain of polio vaccines, with emphasis on environmental sustainability and efficiency, this research offers a significant breakthrough.

## 2. Theoretical Framework

### 2.1 Supply Chain Operations Reference (SCOR) and Green Supply Chain Operations Reference (Green SCOR)

SCOR is a process-based reference model for supply chain operations that can be used to map the supply chain (Zhou, 2022). The SCOR model integrates three key management elements into a cross-functional supply chain framework: business process reengineering, benchmarking, and process measurement (Chopra et al., 2022). Furthermore, according to Saen & Izadikhah (2022) and (Chopra et al., 2022; Bulsara et al., 2016), processes consist of three levels in SCOR. The top level includes five main processes - Plan, Source, Make, Deliver, and Return. This level describes performance from two perspectives: one from the customer's perspective and the other from an internal perspective. At this level, there is a definition of primary competition and instructions on how to achieve it. The explanations of the five processes at level 1 are as follows:

- 1) Planning: arranging supply and demand to fulfill production, delivery, and procurement requirements.

- 2) Sourcing: acquiring products or services to meet market demand. This process includes choosing suppliers, assessing their performance, scheduling supplier deliveries, receiving items, and verifying and authorizing payment for goods provided by suppliers.
- 3) Make: the process of converting raw materials/components into products that meet customer needs.
- 4) Deliver: the processes involved in meeting consumer demand for products and services, often involving distribution, transportation, and border control.
- 5) Return: the process of returning or receiving products for various reasons.

Furthermore, to assess supply chain performance, five categories are utilized: reliability, responsiveness, agility, cost, and asset management. The subsequent step involves the selection of the Key Performance Indicator (KPI) criteria matrix. Given the difficulty for a company to excel in all metrics, it is advisable to prioritize only a select few areas (Huang & Keskar, 2007). The Green SCOR concept has been developed by modifying the SCOR model to incorporate environmental considerations into the SCOR principles. The objective is to enhance the performance of the green supply chain by employing analytical metrics that reflect the relationship between supply chain activities and green concepts (Rosyidah et al., 2022). Furthermore, Rosyidah et al. (2022) and Pulansari & Putri (2020) explicate the four fundamental stages in the development of Green SCOR as follows:

- 1) Ascertain foundational practices and metrics for a green supply chain.
- 2) Assess existing SCOR process models in terms of their environmental implications.
- 3) Tailor the SCOR model by benchmarking exemplary practices and integrating environmental metrics.
- 4) Elucidate the modifications implemented and analyze their ramifications on supply chain operations.

## 2.2 Green Supply Chain Management (GSCM) Performance Measurement.

A fundamental aspect of supply chain management is performance management and continuous improvement. Effective performance management requires a measurement system that can assess the performance of the supply chain as a whole. GSCM is the integration of environmentally friendly concepts into supply chain practices from the product idea, design, sourcing, production process, and distribution to the end of the product life cycle so that it can be recycled, reused, repaired, remanufactured or destroyed so that supply chains and living things can be sustainable (Cazeri et al., 2017). The green supply chain starts from the awareness of the impact of supply chain activities on the surrounding environment. In practice, a green supply chain encompasses the role of the environment in all value-added activities in the supply chain (Kumar et al., 2012).

According to APICS (2017), the Green SCOR metrics used to measure GSCM performance based on the objectives expected by each stakeholder include:

- 1) % of suppliers with ISO 14001 certification.
- 2) % of suppliers meeting environmental requirements.
- 3) % of hazardous materials in inventory.
- 4) % of vehicle fuel from alternative fuels.
- 5) Energy consumption.

Measuring the performance of a green supply chain is crucial for enhancing environmental sustainability in business operations. The benefits of measuring green supply chain performance include the identification of environmental impacts, cost savings, ensuring regulatory compliance, and enhancing supply chain resilience. This measurement impacts sustainable performance in areas such as supplier selection and development, mode and operator selection, vehicle routing, location decisions, packaging options, and more APICS (2017). Tools for measuring GSCM performance from various literatures and practices include analytical hierarchy process, activity-based costing, environmental analysis design, balanced scorecards, and life cycle analysis type tools (Panpatil, Lahane, et al., 2023).

## 2.3 Analytic Hierarchy Process (AHP)

AHP considers the opinions of experts with questionnaires to support decision-making by comparing criteria, sub-criteria, and alternatives. The pairwise comparison matrix assessed by experts shows the importance level between criteria, sub-criteria, and alternatives so that weights are obtained, forming the basis for decision-making (Li et al., 2023). The steps of AHP are as follows (Panpatil, Prajapati, et al., 2023) :

- 1) Constructing a decision hierarchy centered on problem-solving objectives is a fundamental step. It entails the identification of the objectives that must be accomplished, followed by the listing of the relevant criteria and sub-criteria, along with the alternatives to be taken into account.
- 2) Analyze the objectives, criteria, sub-criteria, and alternatives. Create an expert-rated pairwise comparison matrix (using a scale of 1 to 9) to evaluate the criteria against the objectives, the sub-criteria against the criteria, and the alternatives against the sub-criteria.

- 3) Prioritisation. The relative comparative value is then processed to determine the ranking of alternatives.
- 4) Logical consistency. Knowing how good consistency is important because we want to make decisions based on something other than considerations with low consistency.

### 3. Methods

This research was approved by the Logistics Department of PT Bio Farma (Persero) for the Polio Vaccine (OPV) and Inactivated Polio Vaccine (IPV) products. Data on Green Distribution and Green Supply Chain performance were collected from January to December 2023. The Supply Chain Operations Reference (SCOR) is a three-level diagnostic and benchmarking methodology designed to significantly improve a company's supply chain processes. The top level, Level 1, consists of five key processes: planning, sourcing, manufacturing, delivery, and returns. Planning involves coordinating supply and demand to meet production, delivery, and procurement requirements. Sourcing is the activity of obtaining products or services to fulfill market demand. Manufacturing involves transforming raw materials/components into products that satisfy customer needs. Delivery meets consumer demand for products and services, often involving distribution, transportation, and border control. Returns refer to the process of returning or receiving products for various reasons. Level 2 is the configuration level, closely linked to the categorization of each process at Level 1. Level 3 is the implementation element level, further divided into advanced tasks and activities (APICS Supply Chain Council, 2017). Green SCOR is an extension of the SCOR methodology that incorporates environmental concepts into the SCOR process (Zhang & Liu, 2011) by embracing the work attributes of reliability, responsiveness, flexibility, cost, and assets (Qianhan et al., 2010). The next crucial step involves the development of metrics for measuring the performance of green distribution and supply chains, based on the Green Supply Chain Operations Reference (SCOR) model (Huang & Keskar, 2007). The Green SCOR concept expands upon the SCOR model by incorporating environmental principles. The objective is to improve the performance of distribution and green supply chains through analytical metrics that capture the relationship between supply chain activities and green concepts (Rosyidah et al., 2022). Subsequently, the weights of the evaluation metrics at level 1 and level 2 are determined using the Analytical Hierarchy Process (AHP), with input from 5 experts in the logistics department of PT Bio Farma (Persero). AHP utilizes expert opinions to facilitate decision-making by comparing criteria, sub-criteria, and alternatives in a pairwise comparison matrix (Li et al., 2023). The AHP process involves the following steps (Panpatil, Prajapati, et al., 2023):

- 1) Establish hierarchical objectives, criteria, sub-criteria, and alternative structures.
- 2) Evaluate criteria and alternatives through pairwise comparisons, utilizing a scale of 1 to 9 to reflect expert opinions.
- 3) Assess the logical consistency of the experts' judgments.
- 4) Prioritize alternatives based on the highest weighted value for each one.

### 4. Results and Discussion

#### 4.1 Calculation of Actual Value of Green Distribution and Green Supply Chain Performance

In the initial stage, green distribution and green supply chain performance measurement metrics were designed according to the operational characteristics of PT Bio Farma (Persero) based on Green SCOR. Based on the data obtained from the logistics department of PT Bio Farma (Persero), the actual value is calculated for each top-level, consisting of five key processes: plan, source, make, deliver, and return. The calculation results using the designed metrics for measurement are presented in Table 1.

**Table 1**  
Actual Value of Green Distribution and Green Supply Chain Performance for each Green SCOR top-level

No	Metrics Measurement	Formula & Actual value
Plan: Reliability		
1	Inventory level for packaging	$\frac{\text{The average number of products stored in the warehouse}}{\text{Average product demand}} \times 100\%$ (1.85 mio doses / 16.8 mio doses) × 100% = 11,01 %/month
2	Internal meeting	Number of meetings between departments = 2 month
Plan: Responsiveness		
3	Planning schedule	Time to prepare a monthly production schedule = 2 days/month
Plan: Green Supply Chain & Green Distribution		
4	% employee trained on environmental requirements	$\frac{\text{No. of employees trained on gr. supply chain \& gr. distribution}}{\text{Total employees}} \times 100\%$ (921 employees / 921 employees) × 100% = 100 % per year
5	% waste disposition	$\frac{\text{The weight of waste discharged into the environment}}{\text{Total weight of waste produced}} \times 100\%$ (0.982 tons / 127.60 tons) × 100% = 0,77 % per year

Source: Reliability

No	Metrics Measurement	Formula & Actual value
1	Defect rate	$\frac{\text{Number of defective units}}{\text{Number of units shipped}} \times 100\%$ (115 vials/840,000 vials) $\times 100\% = 0,01\%$ per month
2	Source fill rate	The percentage of requests that can be fulfilled by the distribution department = 68 %/ month
3	Number of meetings with project clients	Number of Purchasing meetings with main suppliers = 4 per year
Source: Responsiveness		
4	Purchase order cycle time	The time required to issue a purchase order = 60 days
5	Source Responsiveness	The time needed to find a replacement supplier if the first supplier cannot meet demand = 5 days
6	Source Flexibility	The number of suppliers who can be used as replacement suppliers if the first supplier cannot meet demand = 1 supplier
Source: Green Supply Chain & Green Distribution		
7	% of suppliers with an EMS or ISO 14001 certification	$\frac{\text{No. of suppliers who meet the criteria Gr. Supply Chain}}{\text{Total suppliers registered by the company}} \times 100\%$ (15 suppliers/17 suppliers) $\times 100\% = 88,23\%$
Make: Reliability		
1	% failure in process	$\frac{\text{Number of defective units}}{\text{Number of units produced}} \times 100\%$ (1,400 vials /70,000 vials) $\times 100\% = 2\%$ per production batch
2	Machine material efficiency	$\frac{\text{No. of products processed x standard production cycle time}}{\text{Machine operating time}} \times 100\%$ ((68,600 vials x 0,4 seconds)/28,800 seconds) $\times 100\% = 95,27\%$ per production batch
Make: Green Supply Chain		
3	% hazardous material	$\frac{\text{The amount of hazardous materials used in the production process}}{\text{Total materials used}} \times 100\%$ (200 kg/1,700 kg) $\times 100\% = 11,7\%$ per year
4	% Material that is biodegradable	$\frac{\text{No. of biodegradable material used in the production process}}{\text{Total materials used}} \times 100\%$ (20 tons / 24 tons) $\times 100\% = 83,33\%$ per year
5	Waste produced as % of product produced	$\frac{\text{Weight of waste produced (liquid, solid)}}{\text{Weight of finished product produced}} \times 100\%$ (127.60 tons/200 tons) $\times 100\% = 63,8\%$ per year
6	% of recyclable/ reusable materials	$\frac{\text{The amount of material that can be recycled}}{\text{Total materials used}} \times 100\%$ (20 tons/23 tons) $\times 100\% = 86,9\%$ per year
Deliver: Reliability		
1	Fill Rate	$\frac{\text{Number of products released}}{\text{Total product}} \times 100\%$ (11.08 mio doses/16.80 mio doses) $\times 100\% = 65,9\%$ per month
2	Number of visit to customer	Number of visits to customers for sales promotion of polio vaccine = 2 per month
Deliver: Responsiveness		
3	Delivery to domestic customers	Lead time for distribution of polio vaccine to dometic customers = 14 days per order
4	Delivery to overseas customers	Lead time for distribution of polio vaccine to overseas customers = 14 days per order
Deliver: Green Distribution		
5	% of vehicle fuel derived from alternative fuels (%/year)	$\frac{\text{The amount of gas emissions reduced}}{\text{Total emissions produced before using environmentally friendly fuel}} \times 100\%$ (470.32 metric tons CO2 per year/4,703,244 metric tons CO2 per year) $\times 100\% = 10\%$
Return: Reliability		
1	Customer complaints	1 time per year
2	Return rate from PT. Bio Farma to supplier	$\frac{\text{Number of units returned}}{\text{Number of units received}} \times 100\%$ (0 unit/5490 units) $\times 100\% = 0\%$
Return: Responsiveness		
3	Project Client Repaired Time	60 days

No	Metrics Measurement	Formula & Actual value
4	Product replacement time	60 days
Return: Green Distribution		
5	% of complaint regarding missing environmental requirements from product	$\frac{\text{Number of customer complaints related to environmental issues}}{\text{Total customer complaints}} \times 100\%$ (0/15) × 100% = 0% per year

#### 4.2 Normalized Calculation of the Actual Value of Green Distribution and Green Supply Chain Performance

The next step is to normalize the value for green distribution and supply chain performance. Normalization is needed to equalize the value unit of each metric to a scale of 100. The formula used to normalize the actual value (S<sub>norm</sub>) is:

$$S_{\text{norm}} = \frac{S_i - S_{\text{min}}}{(S_{\text{max}} - S_{\text{min}})} \times 100 \quad (1)$$

An example of normalization calculation for *Source fill rate* is as follows:

$$S_{\text{norm}} = \frac{85-65}{(95-65)} \times 100 = 66,6$$

Table 2 shows the results of normalizing the actual values associated with the worst and best scores for each dimension and metric for the Plan key process.

**Table 2**  
Normalized Value of Plan Performance Metrics

Dimension	No	Metrics	Actual Value (Si)	Worst Score (Smin)	Best Score (Smax)	Score (Snorm)
Reliability	1.	Defect rate	0.01	5	0	99.8
	2.	Source fill rate	85	65	95	66.6
	3.	Number of meetings with Project Client	4	2	4	100
Responsiveness	4.	Purchase order cycle time	60	65	60	100
	5.	Source Responsiveness	5	10	2	62.5
Flexibility	6.	Source Flexibility	1	0	3	33.3
Environmental aspects	7.	% of Suppliers with an EMS or ISO 14001 certification	88.23	76.4	88.23	100

Table 3 shows the results of normalizing the actual values associated with each dimension's worst and best scores and metrics for the Make key process.

**Table 3**  
Normalized Value of Make Performance Metrics

Dimension	No	Metrics	Actual Value (Si)	Worst Score (Smin)	Best Score (Smax)	Score (Snorm)
Reliability	1.	% Failure in Process	2	10	1	88.8
	2.	Machine Material Efficiency	95.27	0	97.2	98.01
Environmental aspects	3.	% of hazardous material	11.7	17.6	11.7	100
	4.	% Materials that are Biodegradable	83.33	0	83.33	100
	5.	Energy use	4,871,888	7,862,631	4,871,888	100
	6.	Water usage	5,000	7,300	5,000	100
Environmental aspects	7.	Waste produced as % of product produced	63.8	100	63.8	100
	8.	% of recyclable/ reusable materials	86.9	0	86.9	100

Table 4 shows the results of normalizing the actual values associated with the worst and best scores for each dimension and metric for the Deliver key process.

**Table 4**  
Normalized Value of Deliver Performance Metrics

Dimension	No	Metrics	Actual Value (Si)	Worst Score (Smin)	Best Score (Smax)	Score (Snorm)
Reliability	1	Fill rate	83	79	90	36.36
	2	Number of visits to customer	2	1	2	100
Responsiveness	3	Delivery to domestic customers	14	21	5	43.75
	4	Delivery to overseas customers	14	21	5	43.75
Environmental aspects	5	% of vehicle fuel emission derived from alternative fuels	10	0	10	100

Table 5 shows the results of normalizing the actual values associated with the worst and best scores for each dimension and the metrics for the return key process.

**Table 5**  
Normalized Value of Return Performance Metrics

Dimension	No	Metrics	Actual Value (Si)	Worst Score (Smin)	Best Score (Smax)	Score (Snorm)
Reliability	1	Customer complain	1	2	0	50
	2	Return rate from PT Bio Farma to supplier	0	2	0	100
Responsiveness	3	Project Client Repaired Time	60	90	30	50
	4	Product replacement time	30	90	30	100
Environmental aspects	5	% of complaint regarding missing environmental requirements from product	0	1	0	100

4.3 Weighting of importance levels 1 and 2 with Analytical Hierarchy Process (AHP)

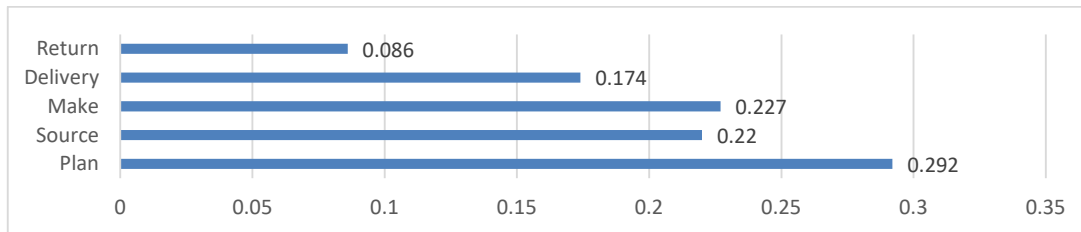
The experts selected to consider the level of importance are the polio vaccine manager, the production manager, the marketing manager, and the distribution manager. These four respondents will complete a set of questionnaires from the pairwise comparison matrix for each level. The level of importance weighting for level one is done by pairwise comparing the key elements of plan, source, make, deliver, and return. The results of the level-one pairwise comparison are shown in Fig. 1.

	Plan	Source	Make	Delivery	Return
Plan		1.41421	1.86121	1.18921	3.13017
Source			1.0	1.10668	3.30975
Make				2.21336	2.05977
Delivery					2.0
Return					

Inconsistency = 0.03 with 0 missing judgements.

**Fig. 1.** Compare the relative importance with respect to: Goal; Distribution and Supply Chain Performance for Polio Vaccine at PT Bio Farma

Based on Fig. 1, the results of pairwise comparisons at level one are consistent because the inconsistency ratio (0.03) value is less than 0.1. Meanwhile, the results of weighting each key element are shown in Fig. 2.



**Fig. 2.** Weighting value for each key element of the Green SCOR matrix level one

In the same way, the calculation of the level two weights can be done, and the results of the weights are used to calculate the final value of the performance of each dimension of Green Distribution and Green Supply Chain, which is presented in Table 6.

**Table 6**  
Calculation of the final value for each measurement dimension

Supply Chain key elements (level 1)	No	Measurement dimensions (level 2)	Score (S)	Level 2 weight (LW)	Total Score (SxLW)	Total Score for each supply chain key element
Plan	1.	Reliability	51.62	0.367	18.94	78.65
	2.	Responsiveness	100	0.389	38.9	
	3.	Environmental aspects	84.95	0.245	20.81	
Source	4.	Reliability	88.56	0.189	16.73	75.48
	5.	Responsiveness	81.25	0.375	30.46	
	6.	Flexibility	33.30	0.231	7.69	
	7.	Environmental aspects	100	0.206	20.60	
Make	8.	Reliability	93.01	0.689	64.08	94.88
	9.	Environmental aspects	99.06	0.311	30.8	
Deliver	10.	Reliability	68.18	0.259	17.65	64.62
	11.	Responsiveness	43.74	0.482	21.07	
	12.	Environmental aspects	100	0.259	25.90	
Return	13.	Reliability	75	0.340	25.50	82.40
	14.	Responsiveness	75	0.364	27.30	
	15.	Environmental aspects	100	0.296	29.60	

In the final step, the total performance value for Green Distribution and Green Supply Chain is calculated and presented in Table 7.

**Table 7**

**Total Performance Value for Green Distribution and Green Supply chain**

No	Supply Chain key elements (level 1)	Total Score for each supply chain key (TS)	Level 1 weight (LW)	Performance (TSxLW)
1.	Plan	78.65	0.292	22.96
2.	Source	75.48	0.220	16.60
3.	Make	94.88	0.227	21.53
4.	Deliver	64.62	0.174	11.24
5.	Return	82.40	0.086	7.08
<b>Total Performance Value</b>				<b>79.41</b>

Based on Table 7, the total performance score for Green Distribution and Green Supply Chain for polio vaccine products is 79.41. According to the APICS standard (APICS, 2017), this overall performance is categorized as "Good." However, this performance can be improved to "Excellent" by improving the key elements and dimensions of the supply chain. The performance improvement can be known by comparing the results of the weighted values of the Green SCOR level one metric element for Plan, Source, Make, Delivery, and Return (Panpatil, Lahane, et al., 2023).

Level 1 metrics are aggregated assessments of Level 2 metrics, and Level 2 metrics are aggregated assessments of Level 3 metrics. Thus, the process of measuring green distribution and green supply chain performance begins with the measurement of processes at the lowest level (Level 3). From the analysis results, the constraints and inefficiencies of the process in the supply chain of polio vaccine products at PT Bio Farma were described, which impact the overall performance assessment. By resolving the constraints and inefficiencies that occur, performance can be improved. The problem was solved using the best practices approach in SCOR version 10.0. Best practices were selected based on the location of Green SCOR Level 2 metric inefficiencies and constraints in the material flow of the polio vaccine supply chain. The proposed best practice is then adapted to the polio vaccine distribution and supply chain conditions at PT Bio Farma as follows:

1. Collaborative planning best practices emphasize the importance of collaborative planning among strategic operations teams. This form of planning can improve the performance of the reliability and flexibility matrices of distribution and supply chains.
2. Best Practice Partnership, which emphasizes the importance of building long-term, trust-based relationships with suppliers and customers. This relationship can increase information transparency, support collaborative planning activities, and avoid PT Bio Farma's insider intervention in passing suppliers who still need to meet the requirements and commitments specified by PT Bio Farma.
3. Best practice transportation management, emphasizing distribution planning so that it can take place optimally and effectively. Transportation management consists of several stages: route planning, route optimization, optimized shipment, and carrier selection.
4. Best practice development of enterprise information system facilitates the implementation of production planning and can integrate existing information in the company. This information is useful for accelerating the order management process, which could have been more effective. At the time of the research process at PT Bio Farma, the development of the Enterprise Information System had just begun and would be applied through the ERP application.

Table 8 details the improvements in Green Distribution and Green Supply Chain performance in key areas.

**Table 8**

**Best Practice Green SCOR to improve the performance of Green Distribution and Green Supply Chain of Polio Vaccine at PT. Bio Farma**

Proses Green SCOR	Best Practice
Plan	<ol style="list-style-type: none"> <li>1. Minimize the use of energy and hazardous materials</li> <li>2. Maintain an environmentally friendly product policy</li> <li>3. Properly handle and store hazardous materials to avoid environmental impact.</li> </ol>
Source	<ol style="list-style-type: none"> <li>1. Gain access to supplier environmental management reports and compliance data.</li> <li>2. Collaborate with suppliers on environmental issues to help implement environmental requirements and sustainable business processes.</li> <li>3. Improve the energy efficiency of lighting and production support systems by efficiently designing warehouse buildings and production areas.</li> </ol>
Make	<ol style="list-style-type: none"> <li>1. Routine measurement of air emissions at the end of each production process.</li> <li>2. Obtain material data sheet system information for raw material handling from suppliers.</li> <li>3. Conduct routine daily inspections of hazardous waste storage areas.</li> <li>4. Conduct benchmarking against similar companies with better environmental management quality.</li> <li>5. Production planning to minimize energy consumption.</li> </ol>
Deliver	<ol style="list-style-type: none"> <li>1. Reduce the use of packaging.</li> <li>2. Perform distribution optimization so that it is optimal and effective, consisting of route planning, route optimization, optimized shipment, and carrier selection to increase the efficiency of vehicle fuel use.</li> <li>3. Selecting a distribution company with no history of environmental violations.</li> <li>4. Use environmentally friendly alternative fuels in vehicles.</li> </ol>
Return	<ol style="list-style-type: none"> <li>Maximize backhaul capacity to reduce excess fuel consumption.</li> </ol>



Our study recommends that the distribution and logistics managers of PT Bio Farma should make improvements according to Table 8 to achieve the future green distribution goal. In addition, by making improvements according to the researcher's recommendations, competitive advantage, cost savings, sustainable use of resources, reduced carbon footprint, compliance with government regulations, and improved corporate image will be achieved (Chopra et al., 2022; S. A. Khan et al., 2020). We also recommend that managers continuously measure and evaluate the performance improvement of green distribution and supply chain to ensure achieving performance goals for polio vaccine distribution in Indonesia.

## 5. Conclusion

The researchers have devised the SCOR metrics, which have proven to be effective in evaluating the performance of green distribution and the green supply chain, resulting in a "Good" rating. To enhance future green distribution performance, it is recommended that collaborative planning be undertaken by strategic operations teams to ensure flexibility. Additionally, the company should place importance on establishing strong partnerships based on trust with suppliers and customers, optimizing green transportation to determine the most efficient distribution routes, and integrating systems with supply chain partners. Further investigations could be carried out to encompass the financial aspects of the company, thereby providing a more comprehensive understanding of its green distribution and green supply chain performance.

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